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(71) Applicant (*for all designated States except US*): MOTIONPOSTER PLC [GB/GB]; 1 The Old Barn, Wicklesham Farm, Farringdon, Oxfordshire SN7 7PN (GB).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): CAUDREY, Jo [GB/GB]; c/o Evtacon Productions Ltd, St Michael's Business Centre, Church Street, Lyme Regis, Dorset DT7 3DB (GB). EVEMY, Jeff [GB/GB]; c/o Evtacon Productions Ltd, St Michael's Business Centre, Church Street, Lyme Regis, Dorset DT7 3DB (GB).

(74) Agent: LIND, Robert; Marks & Clerk, 4220 Nash Court, Oxford Business Park South, Oxford, Oxfordshire OX4 2RU (GB).

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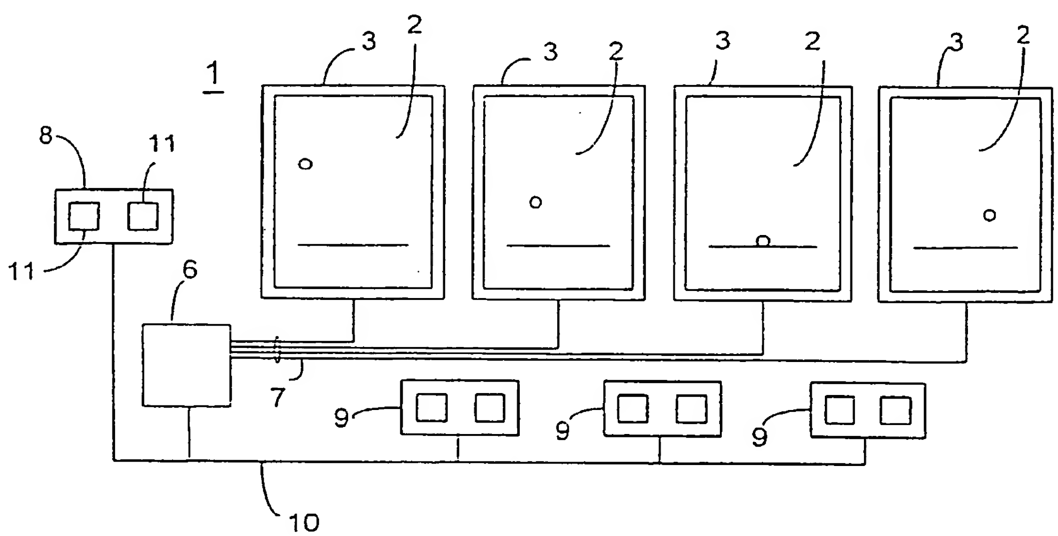

(57) Abstract: An image display system comprising display means (3) for displaying a series of images (2) along the path of a vehicle; lighting (19) for briefly illuminating individual images (2); a plurality of detectors (8,9) arranged to output measurements of the speed of a passing vehicle; and a control unit (6) arranged to control the lighting to illuminate images successively as the vehicle passes at illumination timings based on speed measurements from the plurality of detectors. The control unit (6) is arranged to apply a systematic correction to the speed measurements from the detectors (8,9) based on a statistical analysis of the speed measurements from all the detectors (8,9), which can reduce drift and jitter. The control unit (6) includes a dynamics processing unit (50) arranged to perform non-linear predictive filtering of the speed measurements to produce an instantaneous estimate of the vehicle speed. The control unit (6) also includes a timing generator (60) operating asynchronously of the dynamics processing unit (50) and arranged to derive the illumination timings from the instantaneous speed estimate.

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IMAGE DISPLAY SYSTEM

The present invention relates to an image display system for displaying images to the passengers in a vehicle, for example a train.

There have been prior proposals for image display systems of the type comprising a series of images displayed along the path of a vehicle and lighting for briefly illuminating individual images successively as the vehicle passes. The illumination is sufficiently brief to prevent blurring of the image due to the motion of the vehicle when viewed by a vehicle passenger. Illumination of successive images as the vehicle passes causes the viewer to see the images as a single continuous image at a fixed position relative to the vehicle due to persistence of vision, in the same manner as a television or cinema image. Such an image display system is useful for displaying adverts or written and diagrammatic information, for example about the next station on a train line.

However, with such image display systems, it is difficult to illuminate the image in a stable position relative to the vehicle. There are practical difficulties in deriving sufficiently accurate illumination timings. In practical systems, it is difficult to overcome drift and jitter of the image. Drift occurs in the position at which successive images are illuminated relative to the vehicle such that the continuous image viewed by a passenger drifts away from its initial position, even to a position outside the field of view from a window. Jitter is movement backwards and forwards of the position at which successive images are illuminated relative to the vehicle and is perceived by a viewer as a random movement of the viewed image. Both drift and jitter are annoying to the viewer and reduce the quality of the viewed image because the eye is distracted from the image itself. Experience shows that the spatial accuracy needed is of the order of 0.05% or better. This has prevented many prior proposals succeeding.

The present invention is directed to a system which provides sufficient accuracy in the illuminate timings, in particular allowing the problems of drift and/or jitter to be reduced.

The present invention relates to an image display system using one or more detectors to output repeated measurements of the speed of a passing vehicle and a control means arranged to control the lighting to illuminate the images successively at illumination

timings based on those repeated speed measurements. The aim is to update the measurements of the speed frequently over the time taken for the vehicle to pass the series of images. In principle, the illumination timings derived by the control means are at a rate proportional to the instantaneous speed of the vehicle (and the image spacing). A high update rate of speed information allows the illumination timings based on those speed measurements to track changes in the speed of the vehicle. Otherwise if the illumination timings are based on the wrong speed, drift of the illuminated image occurs. However, in practical image display systems, even with a high update rate drift and jitter are still problems.

According to a first aspect of the present invention there is provided an image display system comprising:

display means for displaying a series of images along the path of a vehicle;

lighting for briefly illuminating individual images;

a plurality of detectors located along the path of the vehicle and arranged to output timing signals as the vehicle passes;

a memory for storing detector positions or relative positions;

processing means for deriving from said timing signals and said stored positions the speed of the passing vehicle, the processing means being arranged to introduce a systematic correction into the derived speed on the basis of an analysis of outputs from the detectors for previously passing vehicles; and

control means arranged to control the lighting to illuminate images successively as the vehicle passes, at illumination timings based on derived speed measurements.

The first aspect of the invention allows jitter and/or drift to be reduced. In fact jitter and/or drift can be caused by inaccuracies in the speed measurement from the detectors. The first aspect of the invention is based on the principle that such inaccuracies are to an extent systematic in a given detector. Therefore asystematic correction of the speed measurements from that detector allow errors in all the speed measurements to be reduced.

Preferably, the control means is arranged to apply, in respect of each one of plural detectors, a respective systematic correction to all the speed measurements from that one of the plural detectors.

It has been appreciated that a major source of jitter in a system employing plural

detectors is that each detector has its own unique systematic error. Therefore, as successive measurements from different detectors are used, a different error is fed into the derived illumination timing. This causes the position of the illuminated image relative to the vehicle to shift depending upon from which detector the current speed measurements are taken. This causes jitter. By applying a respective systematic correction to all the speed measurements from respective detectors, it is possible to reduce this jitter.

This is particularly advantageous where the at least one detector is arranged to detect the time taken for the vehicle to travel a predetermined distance.

This type of detector is useful because of its low cost. However, this type of detector suffers from errors which arise through inaccurate knowledge of the predetermined distance which is time, either because of uncertainty in that distance or because of misalignment of the sensors used in the detectors. Errors caused in this way are unique to a given detector in a given system, but because they are systematic, the present invention provides a powerful way of removing those errors.

According to a second aspect of the present invention there is provided A method of calibrating an image display system comprising a series of images disposed along the path of a vehicle, lighting for briefly illuminating individual images, a plurality of detectors for detecting the passage of a vehicle along said path, and control means responsive to the outputs of said detectors and recorded positions of the detectors to control said lighting, the method comprising monitoring the outputs of said detectors during the passage of a plurality of vehicles, and using the results to adjust the recorded positions of the detectors to calibrate the system.

Systematic errors may be derived by a method according to a third aspect of the present invention, comprising obtaining a plurality of speed measurements from the plurality of detectors; and performing a statistical analysis of the speed measurements from the plurality of detectors to derive the systematic correction for at least one detector.

This method is advantageous because it allows the systematic correction to be calculated specifically for each different installation of the image display system where the systematic errors will be unique to the detectors and the installation. Use of such a statistical analysis provides the derivation of systematic corrections with a great resilience to measurement errors and provides the ability to compensate for long term effects such as

sensor ageing and alignment drift of the sensors in the detector .

Desirably, the plurality of speed measurements are obtained over the passage of a plurality of vehicles. This increases the accuracy of the derived systematic corrections because a great deal of information is accumulated and the effect of random errors is reduced.

The first aspect of the present invention may also be applied to a system in which the detectors include a speed detector arranged to output speed measurements continuously, such as a Doppler speed detector. Such speed detectors are advantageous because they maximise the update rate of speed measurements provided to the control means for deriving the calculation timings. The first aspect of the present invention allows the operation of the speed detector to be improved by additionally providing the system with at least one timing detector arranged to measure the time for the vehicle to travel a predetermined distance and by arranging the control means to apply a systematic correction to the repeated speed measurements from the speed detector based on the output from the at least one timing detector.

Doppler speed detectors and other speed detectors arranged to output speed measurements continuously are inaccurate in absolute terms due to calibration difficulties and/or drift in its properties over time and with temperature. These inaccuracies can potentially prevent practical implementation in an image display system. However, according to the present invention, the inaccuracy may be removed by applying systematic correction based on the output from at least one timing detector. This is effective because the measurement from the timing detector is far more accurate and can effectively calibrate the measurement from the speed detector. As this occurs each time a vehicle passes, the calibration is responsive to drift in the response of the speed detector .

According to a fourth aspect of the present invention, the control means includes processing means arranged to perform non-linear predictive filtering of the speed measurements.

This aspect of the present invention allows the control means to use a better estimate of the instantaneous speed of the vehicle for deriving the illumination timings. This allows both drift and jitter to be reduced. As the filtering is predictive it particularly reduces drift of

the image when the speed of the vehicle is changing. This is because such a predictive algorithm will have a lower group delay, so the estimated speed of the vehicle is more responsive to those changes in speed of the vehicle. In contrast, a filtering approach which is entirely reactive, whilst smoothing out some of the errors in the speed measurements, would be slow to respond to changes in speed of the vehicle because of a high group delay. This would cause drift in the position in the illuminated image relative to the vehicle as the filter speed measurement would change more slowly than the actual speed.

Preferably the non-linear predictive filtering is performed by a state estimator.

According to a fifth aspect of the present invention, the control means comprises processing means including a first unit arranged to process the repeated speed measurements to produce an instantaneous estimate of the speed of the vehicle and a second unit, operating asynchronously of said first unit, arranged to derive said illumination timings from the instantaneous estimate of the speed of the vehicle. Dividing the processing between the first and second units in this way partitions the processing task of the control means into orthogonal components which may be modelled, implemented and tested in isolation. This provides real benefits in designing and implementing the control means to provide greater accuracy in the derived illumination timings. This facilitates the reduction of jitter and drift of the illuminated image required from the vehicle.

An embodiment of the present invention which embodies all the aspects of the present invention, which may themselves be applied in combination, is now given by way of non-limitative example with reference to the accompanying drawings, in which:

Fig. 1 shows a front of an image display system which is an embodiment of the present invention.

Fig. 2 is a view from above of the image display system of Fig. 1.

Fig. 3 is a front view of an image display system having an alternative detector arrangement.

Fig. 4 is a view from above the image display system of Fig. 3.

Fig. 5 illustrates the control unit of the image display system.

Figs. 6 and 7 illustrate actual speed measurements obtained using the image display system of the present invention before and after filtering.

Fig. 8 is aside view of a display unit of the image display system.

Fig. 9 is a cross-sectional view of the display unit of Fig. 8 taken along the line XI-XI;

Fig. 10 is a circuit diagram of a capacitive discharge circuit for the lighting of the image display system; and

Fig. 11 illustrates schematically a system for controlling the illumination of an image display system according to an alternative embodiment of the invention.

Figs. 1 and 2 illustrate an arrangement of an image display system 1 which displays images 2 to viewers on a vehicle such as a train. The system 1 includes a series of images 2 each mounted in a display unit 3 which has lighting (described in more detail below) for briefly illuminating the mounted image 2. The images 2 are

of a suitable size to be seen through a single window of the vehicle, for example A2 where the vehicle is a train.

As illustrated in the front view of Fig. 1, the display units 3 are mounted at the height of the vehicle windows at successive positions along the path of the vehicle. For example as illustrated in Fig. 2, the display units 2 may be mounted on the walls 4 of a tunnel or a cutting through which runs a railway track 5. Alternatively free-standing display units could be used where there is no suitable mounting surface.

Often the images 2 need to be fitted around obstacles along the path of the vehicle, such as alcoves in a tunnel. In this case, the gap between images 2 might increase, but this creates a minimal disturbance to the viewed image and simply alters the frame rate of the viewed image at that point in the series of images 2.

The series of images 2 show a stationary or gradually changing image when viewed successively. The change may create motion in the viewed image, for example like the bouncing ball shown in Fig. 1, or may be a colour change or visual effect. The images 2 may show an advert or useful written or graphic information for example about the next stop for the vehicle. Successive image display systems 1 may be used in sequence to display an image over an extended time.

The image display system 1 further includes a control unit 6 which provides control signals to the lighting of respective display units 3 over respective control lines 7. The control unit 6 can control the illumination of a series of images 2 of any number. Although the image display system 1 is shown in Fig. 1 for clarity as having only four images 2, desirably the number of images 2 is large, typically 24, to reduce the number and hence cost of control units 6 for a long image sequence.

The control unit 6 derives the appropriate illumination timings based on speed measurements obtained from a plurality of detectors 8, 9 over a signal line 10 and is described in more detail below.

The detector arrangement is as follows.

A first detector 8 is mounted at the height of the body of the vehicle, at the leading edge of the series of images 2. The first detector 8 has a pair of sensors 11 disposed a predetermined distance apart. The sensors 11 detect radiation from an

infra-red light-emitting diode source 12 disposed in the opposite side of the track 5. The source 12 provides respective beams 13 of radiation to the two sensors 11, so that the sensors 11 detect when a passing vehicle breaks the beams 13. The detector 8 outputs on signal line 10 to the control unit 6 a signal representing the time difference between the two beams 13 being broken as a measurement of the speed of the vehicle.

The first detector 8 is also used to provide a highly accurate positional reference. The output of the detector 8 is used by the control unit 6 as reference timing pulses for the front and rear of the vehicle.

In addition, there are a plurality of further detectors 9 which have an identical instruction to the first detector 8 including sensors 11 a predetermined distance apart to sense respective beams 14 from respective infra-red light-emitting diode sources 15 disposed on the opposite side of the track 5. The detectors 9 and sources 15 are mounted at the height of the wheels of the vehicle below the bogie structure of the vehicle, approximately 50 mm above rail level. The beams 14 are cut by the rims of successive wheels. The advantage of the further detectors 9 being at wheel-height is that they each obtain speed measurements from each of the wheels of the vehicle of which there are typically many. Therefore a few further detectors 9 can provide frequently updated speed measurements. The further detectors 9 output over signal line 10 to the control unit 6 a signal representing the time difference between the two beams 14 being broken as a measurement of the speed of the vehicle.

The detectors 8, 9 provide accurate measurements of the speed of the vehicle. The only limit on this accuracy is the tolerance in the relative positioning of the sensors 11 and the relationship between the separation of the sensors 11 and the beam width which is itself controlled by the optics of the sensors 11.

However, the exact form of the detectors 8, 9 used is not essential. The guiding principle is to provide detectors which output speed measurements repeatedly over the passage of the vehicle past the series of images 2 so that the illumination timings derived by the control unit 6 are based on frequently updated speed measurements.

The positions of the detectors 9 along the vehicle may be selected in any

manner and are not restricted to the positions shown in Fig. 1. Desirably the detectors 8, 9 are arranged such that the maximum distance travelled by the vehicle between the speed measurements is less than 5 metres throughout the passage of the length of the vehicle. A single detector 9 will provide speed measurements during the passage of wheels on a bogie. Typically, the wheel spacing on a single bogie is 2 to 3 metres, but the gap between the bogies is typically greater than the desired minimum spacing of 5 metres. Therefore plural detectors are used. For a long vehicle, to minimise the maximum distance travelled by the vehicle between readings it is desirable to space the plural detectors by a spacing equal to the length of a carriage of the vehicle, over which the bogie structure repeats, divided by the number of detectors.

Ideally several detectors 9 are spaced in front of the series of images to provide a lead-in during which the control means processes the speed measurements allowing proper operation of the filtering processes performed in the control means 6, prior to illumination of the images 2. Furthermore, deployment of detectors 8, 9 at the beginning and at the end of the series of images 2 ensures that speed measurements are available throughout the passage of the entire length of the vehicle past the entire length of the series of images 2.

The detector 8, 9 could be positioned to detect any feature of the vehicle, typically on the undercarriage or roof.

Timing detectors like the detectors 8, 9 of the image display system 1 which measure the time for the vehicle to travel a predetermined distance are advantageous because of their low cost, but may take other forms. Instead of detectors having two sensors a predetermined distance apart, the detectors could have a single sensor arranged to detect two features of the vehicle itself which are a known predetermined distance apart, for example marking applied to the vehicle. The sources need not be arranged on the opposite side of the path of the vehicle, but could be arranged adjacent the sensors to detect reflected radiation. The use of infra-red radiation is not essential but is preferred to reduce the chances of false triggering and to prevent the radiation being visible. Instead of outputting a signal representing a time difference, the detectors could output pulses on detection of a feature of the vehicle which are

subsequently filtered to derive a speed measurement.

As an alternative to timing detectors, speed detectors which output speed measurements continuously are advantageous in terms of providing very frequent measurements. Examples of such speed detectors are Doppler speed detectors which use the frequency shift of reflected electromagnetic or acoustic waves or time-of-flight speed detectors which derive speed information from the time of flight of electromagnetic or acoustic pulses reflected from the front or rear of the vehicle.

In general, the detectors can use a combination of technologies such that the effects of each supplement one another in providing speed measurements to the control unit 6.

Figs. 3 and 4 illustrate a further image display system 16 employing an alternative detector arrangement from the image display system 1 of Fig. 1. Apart from the detector arrangement, the image display system 16 of Fig. 3 and 4 is identical to the image display system 1 of Figs. 1 and 2, so is not described again. The detectors of the image display system 16 include a first detector 17 which is identical to the first detector 8 of the image display system 1 of Figs. 1 and 2, so is not described again.

In addition, there is a further Doppler speed detector 18 positioned at the rearward end of the series of images 2. The Doppler speed detector 18 is a known K-band Doppler speed detector operating at around 24 GHz or alternatively an X-band detector operating at around 10.5 GHz. It uses the frequency shift of microwaves reflected from the vehicle to output speed measurements continuously. The Doppler speed detector 18 faces along the path of the vehicle to provide continuous speed measurements as the vehicle passes the series of images 2. In fact, the measurements from the Doppler speed detector 18 has a low absolute accuracy but is calibrated by the control unit 6 using the output from the first detector 17 as described further below.

Optionally a further Doppler speed detector could be used for example positioned at the front end of the series of images 2 facing rearwardly.

The control unit 6 is illustrated in diagrammatic form in Fig. 5.

The control unit 6 consists of two processing units, namely a dynamics

processing unit 50 and a timing generator unit 60. The dynamics processing unit 50 processes the speed measurements input on the single line 10 from the detectors 8,9 and processes them to derive an instantaneous estimate of the speed of the vehicle. The dynamics processing unit 50 supplies the instantaneous estimate of the speed of the vehicle and a timing reference to the timing generator unit 60 which uses this information to derive illumination timings. The timing generator unit 60 outputs control signals to the respective display units 3 on the control line 7 at those illumination timings to cause illumination of successive images 2.

The dynamics processing unit 50 and the timing generator unit 60 operate asynchronously, and are in fact implemented using separate processor systems. This separation of functionality between two units operating asynchronously separates the processing performed by the control means 6 into two components which may be modelled, implemented and tested in isolation. This simplifies the design of the control unit 6 which in turn provides real benefits in improving the accuracy of the illumination timings derived by the control unit 6.

The dynamics processing unit 50 is now be described in terms of various function blocks, which may each be implemented by any suitable signal processing circuit.

The speed measurements input to the dynamics processing unit 50 on control line 10 are first processed by a pre-processing block 51 which performs various types of signal processing.

Firstly, the pre-processing block 51 performs pre-filtering of the speed measurements to remove noise. This is particularly advantageous in the case of measurements from a detector providing measurements continuously, such as the Doppler speed detection 18 of the image display system 16 of Fig. 3. In general, through the passage of the vehicle past the detectors, the signal-to-noise ratio changes. As there are no other moving components, this is due to multi-path reflections from the vehicle. In all cases the noise is at a lower frequency than the required signal as the angle of incidence to the vehicle is non-perpendicular. Non-symmetric and possibly non-linear filtering methods can use this knowledge in the implementation of a filter such as a phase-locked loop arranged to extract the main

data. In addition, allowance must be made for non-perpendicular incidence of the primary signal when the vehicle is nearby.

In an alternative implementation in which the detectors simply output a pulse on detection of the passage of a feature of the vehicle, instead of outputting a time difference, the signal processing block 51 filters these pulses to extract the speed information. The filtering can take advantage of knowledge of the physical layout and dimensions of the features.

Secondly, the pre-processing block 51 can apply a systematic correction to the speed measurements. The systematic corrections are applied by multiplying speed measurements by one or more correction factors, although correction could be applied in other ways. The correction factors are supplied by a calibration block 52 which will be described in detail below.

Firstly, an absolute correction factor is applied to all the speed measurements from all the detectors 8,9 to effect an absolute calibration of the speed measurements.

Secondly, respective correction factors are applied to the speed measurements from different ones of the detectors 8,9. In this way, each of the detectors 8, 9 receive its own systematic correction. This is particularly significant because each detector has its own unique systematic error which is unique to that detector 8, 9 and in general different for different installations of the image display system 1. For example such errors may arise through inaccurate knowledge of the predetermined distance arising through misalignment of the sensors 11 used in the detectors 8, 9. In the case of the further detectors 9 mounted at wheel height, vertical mis-alignment is a major source of such systematic errors. Such mis-alignment is caused by the mounting position of the further detectors 9 or by vertical movement of the vehicle or track on which it runs, because it causes the wheels of the vehicle to break the respective beams for T at different horizontal positions as the rim of the wheel is not vertical but at an angle because it is circular. As each detector 8, 9 has its own systematic error, speed measurements from different detectors can cause corresponding errors in the derived illumination timings, which will be seen as jitter. In fact, this can be the major source of jitter. However, by applying respective corrections which are specific to each detector, this jitter can be removed or at least

reduced.

The pre-processing block 51 outputs the pre-processed speed measurements to a filter block 53. The pre-processing block 51 also outputs reference timing pulses which are supplied directly to the timing generator unit 60 as a timing reference in deriving the illumination timings. The timing reference pulses are preferably the output of the first detector 8 caused by the front and rear of the vehicle as it arrives at the image display system 1.

The filter block 53 filters the pre-processed speed measurements to produce an instantaneous estimate of the speed of the vehicle which is subsequently fed to be the timing generator unit 60.

The filter block 53 is a non-linear predictive filter, in fact a state estimator such as a Kalman, MiniMax or other hybrid combination, although other non-linear predictive filtering algorithms could be used. The state estimation is based on a state vector 54 containing the values of the current position, velocity and acceleration of the vehicle. The filter block 53 uses a predictive algorithm to derive an instantaneous estimate of the speed of the vehicle from the speed measurements. The algorithm relies on known factors about the vehicle, including Newtonian equations of motion, conditions that there is no discontinuity of position or velocity, and conditions on the changes in acceleration being within predetermined limits and expected characteristics.

As an alternative, the filter block 53 could be implemented by a linear filter instead of a non-linear predictive filter. However, such a linear filter can only be responsive to the speed measurements and whilst the response is deterministic it is only possible to minimise group delay at the expense of instability. Therefore, a non-linear predictive filter is preferred because it gives an improved group delay, so the estimated velocity is more responsive to changes in speed of the vehicle.

The estimated speed of the vehicle output by the filter block 53 is fed to the timing generator unit 60 through a low-pass filtering block 55. Inevitably, absolute accuracy of the estimated speed is impossible, in particular as the vehicle accelerates or decelerates in an unpredictable manner. The low-pass filtering block 55 has a response characteristic which controls the estimated speed in this case. Its low-pass

filtering characteristic is selected to reduce high frequency jitter, although this must be balanced against the need to minimise group delay.

The timing generator unit 60 will now be described.

The fundamental operation of the timing generator 60 is to derive illumination timings appropriate to cause illumination of successive images at a fixed position relative to the vehicle. This is done based on the estimated speed of the vehicle derived by the dynamics processor unit 50 based on the speed measurements. It is also based on the reference timing pulse 50. At the appropriate illuminations timings, the timing generator 60 outputs a control signals to the respective display units 2 over the control lines 7 through an array of driver circuits 70 arranged to convert the digital control signals to a sufficient level.

In order to illuminate successive images 2, the timing generator unit 60 takes into account the positions x_i of the images 2 relative to a display system reference position, namely the position of the first detector 8. By storing the image position x_i accurately, it is possible to control the timing for each image 2 of the series to be illuminated at an identical position relative to any given window. This prevents sideways shifting of the viewed image from one image to the next.

The image position x_i are represented by a bit pattern known as the "image map". Individual bits of the image map represent the presence or absence of an image 2 at positions a constant predetermined spacing r apart. For example if the image map was 00101001, then this would represent the presence of images at positions $x_i = 3r$, $5r$ and $8r$.

As the control unit 6 illuminates the series of images for different windows of the vehicle, the timing generator unit 60 also takes into account the positions x_w of each window relative to a vehicle reference feature on the vehicle, namely the front of the vehicle which is detected by the first detector 8.

The respective window positions x_w are represented by a bit pattern known as the "vehicle map". The individual bits of the vehicle map represents the presence or absence of a window at the positions predetermined spacing r apart. For example, if the vehicle map is 10100101, this would represent the windows being at positions $x_w = r$, $3r$, $6r$ and $8r$.

The image map and vehicle map are stored in a memory in the timing generator unit when the image display system 1 is installed.

The timing generator unit 60 starts operating on receipt of a reference timing pulse indicating detection of the vehicle reference feature, ie. the front of the vehicle. Then the vehicle map and image map are used to derive the illumination timings in real time by relatively shifting the bit patterns at a rate proportional to the estimated speed of the vehicle output from the dynamics processing 50 and inversely proportional to the predetermined spacing r. Illumination timings are derived by recognising coincidence of respective bits of the image map and vehicle maps which occurs when the corresponding window and image are adjacent one another. The control signals are output on the corresponding control line 7 when this coincidence occurs. This is achieved by shifting the image map along a shift register at a predetermined shift timing t_s based on the instantaneous estimate of speed v according to the equation:

$$t_s = r/v \tag{1}$$

Each shift of the shift register has the effect of integrating the inverse of the velocity over units of the spacing r. The image map is used to map individual bit positions of the shift register to respective images 2. This is achieved by the image map being used to switch the positions of the shift register to respective control line 7 for the corresponding image 2. The bits of the shift register at which the image map indicates the presence of image are output as the control signal. Therefore the shift register automatically creates control pulses in real time on the control lines 7 at the correct illumination timings. The shift register is a desirable way to achieve this because it allows the timings to be derived with a minimum amount of processing power, as well as handling the supply of simultaneous control signals to different images 2, because the bits are supplied from the shift register along the control line 7 in parallel with one another.

The size of the predetermined spacing r is the resolution of the image map and vehicle map. Any value for the predetermined spacing may be chosen depending on the requirements for display on the vehicle and the side for the image display in question. In general, it is desirable to use a small predetermined spacing to avoid

restriction on the positioning of the display units 3. This has the overhead of increasing the length of the bit patterns constituting the vehicle map and tunnel map, but such long bit patterns are easily handled by the timing generator 60.

The timing generator unit 60 also derives synthetic reference pulses for the reference features of the vehicle, namely the front and rear of the vehicle. The synthetic reference pulses are output to the calibration block 52 of the dynamics processing unit 50 for use in calibrating the system as described in detail below. The synthetic reference pulses are derived in exactly the same manner as the control pulses for the lighting output on the control lines 10. Therefore the period between the synthetic reference pulses is the time for the vehicle to travel a distance equal to the difference between the reference features as estimated using the same processing as is used to derive the illumination timings.

The timing generator unit 60 is implemented by a microprocessor running an appropriate program.

The timing generator unit 60 could in fact derive the illumination timing in many different ways. The illumination timings may be calculated using a microprocessor using numerous different algorithms. If the image spacing is constant, no image map is necessary. Similarly, the vehicle map is unnecessary if the images are positioned at a fixed spacing relative to the vehicle. In this case, the illumination timings must simply be derived at a rate inversely proportional to the speed, so may be derived by a frequency generator the frequency of which is based on the estimated speed.

Whilst it is desirable to store an image map and vehicle map to allow the system to adapt to different installations and vehicles, this information may instead be implicit in the algorithm used by the timing generator unit 60.

The operation of the calibration block 52 is now described. The calibration block 52 is implemented by a microprocessor running an appropriate program. The calibration block 52 performs various operations for the purpose of calibrating the dynamics processing unit 50.

The calibration block 52 receives and stores speed measurements output from the pre-processor 50, although it could equally use the raw speed measurements

output directly from the detectors 8, 9.

The calibration block 52 analyses the speed measurements. This analysis is performed off-line, that is between the passage of vehicles. This allows the analysis to be based on an entire set of speed measurements from a passing vehicle. It also allows the analysis to be based on speed measurements from plural vehicles. Thus these points improve the quality of the analysis.

The first process performed by the calibration block 52 is applicable to the image display system 1 of Fig. 1 any image display system having a plurality of detectors. The first process is to calculate a respective correction factor for each of the respective detectors 8, 9. Each calculated correction factor is supplied to the pre-processing block 51 where they are used to apply systematic corrections to the speed measurements from the corresponding detectors 8, 9, as descried above.

The basis for the calculation performed in the first process is as follows. A typical set of speed measurements are shown in the graph of Fig. 6 in which the vertical axis shows the speed in metres per second and the horizontal axis shows time in seconds. These measurements were taken by an image display system in accordance with Fig. 1 having eight wheel-height detectors 9. The speed measurements for each detector is plotted by a different symbol. As the vehicle has eight wheels, there are eight speed measurements from each detector.

The speed measurements exhibit systematic and random errors. An example of a random error is the abnormally high value of the first measurement denoted by a cross (the third measurement overall). Such random errors are removed by the filtering performed in the filter block 53.

More significantly, the measurements from each detector exhibit an error which is systematic to that detector. For example, looking at the right hand side of the graph, the final measurements from the detector denoted by circles are generally high, whereas the measurements from the detector denoted by crosses are generally low. If such systematic errors are not removed, this causes significant jitter of the illuminated image, because the error in the speed measurements causes a corresponding error in the illumination timings and hence the position of the illuminated image relative to the vehicle. Therefore jitter is produced as the

illumination timings are based on successive speed measurements from a different detector having a different systematic error. The first process derives calibration factors intended to reduce this systematic error. Thus the first process is to calculate a correction factor that fits the speed measurement from that detector to all the speed measurements from all the detectors, using a statistical analysis.

Firstly, the speed measurements are filtered using a classical smoothing filter such as a Gaussian or polynomial least squares fit. An example of this for the example data set of Fig. 6 is shown by the solid line. Preferably a Gaussian kernel is used to compute a locally weighted average v_f over adjacent samples v_m according to the equation:

$$v_f(t) = G(v_m(t)) \tag{2}$$

Subsequently the correction factor is calculated as the mean of the actual speed measurements to the filtered speed measurements at the same time. Preferably, the geometric mean is calculated. From the speed measurements from the passage of a single vehicle, the correction factor CF_s for the sensor s which has n measurements available at times t_j (where j = 0,1...,n) is calculated as the geometric mean according to the equation:

$$CF_s = \sqrt[n]{\prod_{j=1}^{n} \frac{v_m(t_j)}{v_f(t_j)}} \tag{3}$$

From the measurements from the passage of k vehicles, the correction factor CFP_s for the sensor s is calculated from the correction factors CF_s calculated in equation (3) according to the equation:

$$CFP_s = \sqrt[k]{\prod_{j=1}^{k} CF_s(k)} \tag{4}$$

The correction factors CFP_s for each sensor are supplied to the pre-processing block 51 which uses them to apply systematic corrections to all the speed measurements from the respective detector 8, 9. This significantly reduces the jitter

between the speed r[illegible]urements from different detectors and s[illegible]arly reduces the jitter in the position of the illuminated image relative to the vehicle. This is apparent from the graph in Fig. 7 which shows the speed measurements of Fig. 6 after multiplication by the respective correction factors. As can be seen, the systematic correction fits the speed measurements from each sensor to the filtered speed profile derived from all the speed measurements, shown by the continuous line.

The benefits in performing this first process off-line are as follows. Firstly, the filter function is more effective as it uses future and past measurements which is of course impossible in real-time when only past measurements are available. Secondly, it allows the use of speed measurements from the passage of plural vehicles. This provides greater resistance to non-systematic errors, because these are random and uncorrelated between the passage of different vehicles. The first process could be applied to any image display system having a plurality of detectors or to one or more detectors (ie not all the detectors) known to be less accurate.

The second process performed is applicable to the image display system 16 of Fig. 3 including a Doppler unit 18.

The basis for the second process is as follows. A speed detector outputting speed measurements is continuously desirable because it allows the control unit 6 to respond to changes in the speed of the vehicle when deriving illumination timings which hence in its drift in the position of the illuminated image relative to the vehicle. In fact the outputs from the Doppler speed detector 18 or other speed detectors can also provide very accurate measurements of the speed relative to one another, but in absolute terms the speed measurements are not particularly accurate and drift over time due to thermal drift and ageing of the circuitry.

This problem is overcome by multiplying all the speed measurements from the Doppler speed detector 18 by a correction factor which has the effect of calibrating those speed measurements to be accurate in absolute terms. The second process calculates an appropriate correction factor based on the speed measurements from the Doppler speed detector 18 and outputs from the timing detector 17 which measures the time taken for the vehicle to pass a predetermined distance. In the second process, the calibration block 52 uses the output of the detector 17 from the

front and rear of the vehicle as timing pulses between which the vehicle travels a predetermined distance, namely the length of the vehicle. Alternatively, it could use the outputs from each sensor 11 of the timing detector 17 between which the vehicle travels a predetermined distance equal to the spacing between the sensors 11, but this provides less accurate calibration.

The second process is as follows. The speed measurements from the Doppler speed detector 18 are integrated over the period of time between the timing pulses. This integral gives a measured value x of the distance travelled by the vehicle based on the output of the Doppler speed detector 18. Then the correction factor F necessary to adjust the measured value x to the actual value of the predetermined distance d is calculated according to the equation:

$$F = d / x \qquad (5)$$

This correction factor F is thus the correction factor by which the speed measurements must be multiplied to calibrate them. The calibration block 52 calculates correction factors F over the passage of plural vehicles and obtains a mean correction factor which is supplied to the pre-processing block 51.

The second process may be applied to any detector arrangement including a speed detector outputting measurements continuously and another detector used to calibrate them.

A third process performed by the calibration block is to calibrate an absolute correction factor to be applied to all the speed measurements output from all the detectors 8, 9 to calibrate the control unit 6 as a whole. To achieve this, the calibration block 52 receives timing reference pulses from the detector 8 (or 17) on detection of reference features of the vehicle, namely the front and the rear. The calibration block 52 also receives synthetic reference pulses derived from the timing calculation unit 60 representing the timing of the reference features derived by the processing of the control unit 6. The period between the timing reference pulses is the actual time taken by the vehicle to travel the distance between the reference points, ie. the length of the vehicle. The period between the synthetic reference pulses is equal to the estimated time for the vehicle to travel between the reference points as estimated by the calculation process performed in the control means 6.

This is equivalent [redacted] distance between the reference points [redacted] by an integral of the inverse of the estimated velocity output by the dynamics processing unit 50 between reference points stored in the timing calculation unit 60. When the control means is calibrated, these periods should be equal, but otherwise they will be different. The ratio of the periods between the timing reference pulses and the synthetic reference pulses is calculated because it represents the fractional error in the estimated time as compared to the actual time between the reference points. The ratio is averaged over the passage of plural vehicles. The mean ratio is supplied to the pre-processing block 51 which uses it as a correction factor for all the speed measurements output by all the detectors.

A fourth process performed by the calibration block 52 is to perform a statistical analysis of all the speed measurements to derive statistical parameters for use by the filter block 53. The non-linear predictive filtering processing performed by filter block 53 uses statistical parameters for estimation and measurement noise. Appropriate selection of the statistical parameters can improve the operation and performance of the filtering. The fourth process is to derive these statistical parameters from the speed measurements.

Firstly the correction factors for the individual sensors calculated in the first and second processes are statistically analysed to obtain the variance of the measurement noise, both across the system as a whole and specific to each individual detector.

Secondly, the variance of the estimation error is derived from the measured values v_m of the speed measurements and the filtered values v_f derived in the first process. This variance E may be calculated from p speed measurements by the equation:

$$E = \sum_{j=0}^{P} (v_m(tj) - v_f(tj))^2 \qquad (6)$$

The variations of the measurement error and the estimation error are fed to the filtering block 53. The filtering block 53 uses these variants to control the filtering process.

The display units 3 and lighting are now described.

Each display unit 3 houses a capacitive discharge circuit 18 which fires lighting 19 to illuminate the image 2 in that display unit 3. The form of the capacitive discharge circuit 18 and the lighting 19 are described in detail below. Each of the control lines 10 is connected to and triggers the capacitive discharge circuit 18 of a single display unit 3.

The display unit 3 is illustrated in Figs. 8 and 9. The base of the display unit 3 is performed by an open-topped box 20 formed from sheet-metal or other material which is mounted in any orientation to a mounting surface adjacent the path of the vehicle. The open surface of the box 20 is covered by a transparent base sheet 21 of glass. The image 2 is printed transparency positioned on the base sheet 21. The display unit 3 has a hinged frame 22 supporting a transparent cover sheet 23 of glass. The frame 22 is openable (to the position shown in Fig. 8) to allow removal and insertion of an image 2 and closable to hold the image 2 sandwiched between the base sheet 21 and cover sheet 23.

Although the above described form of display unit 3 is preferred for simplicity and ease of changing the images 2, alternative forms of display unit may also be used. For example, the display units could be constituted by an LCD display or other controllable to show a selectable image 1. This would have the advantage of avoiding the need to physically change mounted images. Preferably, the LCD display would be illustrated by backlighting as described above. Currently the cost of LCD displays would be prohibitive but the system is technically feasible and the cost is likely to reduce to an acceptable level.

Another alternative is to use a front-lit poster. However, it is preferable to use backlighting because in the unlit state a transparency reflects less ambient light and is darker than a poster, particularly outdoors. This means the unlit transparency will be less visible and will not affect the viewed image.

The images may instead be projected by an optical system from a small transparency onto the face of the display unit which acts as a screen. This has the advantages that no image at all is visible when the lighting is off and that the image may easily be changed. However an optical system of appropriate quality is

expensive and it is difficult to obtain images of sufficient quality.

Within the display unit 3, the capacitive discharge circuit 18 is formed on a printed circuit board 24 mounted to the base of the box 20. The capacitive discharge unit 18 causes the lighting 19 to be illuminated for a period of time sufficiently brief to prevent blurring of the illuminated image 2 when viewed from the vehicle. In effect, the image 2 is perceived by the viewer to move by an amount equal to the speed of the train multiplied by the period of the illumination and this movement can blur the viewed image 2. Therefore the period must be short relative to the speed of the vehicle preferably of the order of 1ms or less, preferably 0.5ms or 0.1ms or less.

The level of illumination must be sufficiently high to make the image 2 visible despite the brief period of illumination. The image display system will work in any ambient light conditions, including daylight, provided the illumination is sufficiently intense relative to the ambient light. Therefore, the intensity of the lighting is selected to be sufficient for the ambient light where the system is to be used.

To meet these requirements, the lighting consists of at least one xenon discharge lamp 19, although other gas discharge lamps or strobe lamps could be used. In fact, four xenon discharge lamps 19 mounted, both physically and electrically, to the printed circuit board 24. The discharge lamps 19 are spaced around the periphery of the printed circuit board 24 to spread the light generated by the discharge lamps 19 across the rear face of the image 2.

The capacitive discharge circuit 18 is designed to meet the above requirements for brief, bright illumination, as follows. The circuit diagram of the capacitive discharge circuit 18 is illustrated in Fig. 10. For clarity, the circuit diagram of Fig. 10 shows only a single discharge lamp 19, whereas in fact all the circuit elements shown in the dotted line in Fig. 10 are replicated for each discharge lamp 19 in parallel with one another.

Each discharge lamp 19 has two discharge capacitors, in particular a main discharge capacitor C3 and an attack discharge capacitor C2. The main discharge capacitor C3 is a substantial electrolytic capacitor (typically 33 to 100 μF and preferably 68 μF) which provides the main energy source for the discharge that lights

the discharge lamp 19. The main discharge capacitor C3 has a low internal resistance and is formed to withstand the high current impulse requirements during discharge. The attack discharge capacitor C2 is a smaller device (preferably 0.1 or up to, say, 1 μF) which is non-electrolytic and has a very low internal resistance and inductance for the purpose of providing a faster attack to the flash dynamic characteristics. The discharge capacitors C3 and C2 are connected in parallel with the xenon discharge lamp 19.

The control line 7 is connected to a control terminal 25. The control signal from the control unit 6 is supplied from the control terminal 25 to a thyristor TH1 through a first optocoupler O1 of a conventional transistor type. The thyristor TH1 forms part of a triggering circuit together with a resistor R2, a capacitor C4 and a transformer T1 connected in a conventional manner to provide an EHT trigger pulse to the discharge lamp 19, thereby to trigger discharge of the discharge capacitors C3 and C2 through the lamp 19.

The capacitive discharge circuit 18 further includes a charging circuit for charging the discharge capacitors C2 and C3 from an AC 240V mains supply connected to a pair of terminals 26. The charging circuit includes a bridge rectifier D1 to rectify the mains supply and provide a rectified DC supply across positive and negative supply rails 27 and 28. The rectified DC supply is supplied to the discharge capacitors C2 and C3 through a diode D2 and an inductor L1 in series with the discharge capacitors C2 and C3. The inductor L1 is a conventional fluorescent tube choke type. The ability to use this type of inductor would provide significant cost saving as it is far cheaper than any other type of inductor of a comparable size.

A switch S1, in the form of a transistor switch which may be implemented by bipolar or MOSFET transistors, is connected in series with the inductor L1. The switch S1 has the purpose of disconnecting the discharge capacitors C2 and C3 and the lamp 19 from the supply when the lamp 19 is triggered. Therefore, the switch S1 is switched on the inverse phase of the control signal supplied to thyristor TH1 by supplying the control signal from the terminal 25 to the switch S1 through a second octocoupler O2 normally of a conventional transistor type. This prevents current from passing directly to the lamp from the supply during illumination of the

discharge lamp 19. [redacted] prevents the duty cycle of the supply [redacted] imposed on the output of the strobe lamp and prevents the lamp 19 from entering a harmful mode of operation.

In addition, the mains supply is fed to the bridge rectifier D1 through a resistor R1, and there is a reservoir capacitor C1 connected between the positive and negative supply rails 27 and 28. The current limiting resistor R1 and the reservoir C1 are optional, for reasons discussed below.

The operation of the capacitive discharge circuit 18 will now be described.

After the mains supply is applied, current passes through the diode D2, inductor L1 and switch S1 to charge the discharge capacitors C2 and C3 until the voltage prevents current flow through the diode D2. Under normal conditions this voltage is in the range of 270V to 400V. This is the quiescent condition of the capacitive discharge circuit 18.

When the control signal is supplied to the control terminal 25, the discharge lamp 19 is triggered causing the charge on the discharge capacitors C2 and C3 to discharge through the lamp 19 creating the brief period of illumination required. Of course, all four strobe lamps 19 are triggered at the same time. During this time, the switch S1 is switched off by the control signal, thereby disconnecting the supply from the lamp 11 so that the only current flowing through the lamp 11 is the discharge current from the discharge capacitor C2 and C3.

Immediately after the trigger is removed, the switch S1 closes and the discharge capacitor C2 and C3 are charged via the inductor L1. The use of the inductor L1 in the charging circuit provides a number of advantages, as follows. The charging characteristics are determined by the predominantly LC circuit formed by the combination of the inductor L1 with the discharge capacitors C2 and C3. The resultant LC charge curve is characterised by the initial part of the sine curve. Accordingly, the charge time to peak voltage is quick but without creating an excessive charging current. Control of the charging current is important as an excessive charging current may damage components. The charging current is proportional to the slope of the charge curve because it is equal to the total capacitance of the discharge capacitors C2 and C3 multiplied by the rate of change of

voltage. The LC charge curve 20 is nearly linear over the charging. This contrasts with the charging of a conventional capacitive discharge circuit through a resistor which will have an RC characteristic. The use of an inductor in the charging circuit adds an improved balance between obtaining a fast charge time without creating an excessive charging current.

In addition, the provision of the inductor L1 means that current is limited by the reactance of the inductor L1, rather than by a resistive element, so there is less energy wastage.

Furthermore, the use of the inductor L1 allows the energy stored in the inductor L1 to be fed forward to the discharge capacitors C2 and C3 in order to increase the operating voltage of the system as a whole. This reduces the size of the discharge capacitors C2 and C3 required for a given output energy. As the energy is directly proportional to the capacitance of the discharge capacitors, but proportional to the square of the voltage, this allows for far smaller capacitors and therefore produces significant cost savings.

To utilise the energy stored in the inductor in this way, the charging circuit includes the reservoir capacitor C1 connected across the supply and therefore in parallel with the series assembly of the discharge capacitors C2 and C3 and the inductor L1. The reservoir capacitor C1 is a large electrolytic capacitor (preferably 220 μF) having a capacitance significantly larger than the discharge capacitors C2 and C3 which conversely have a lower capacitance than if the reservoir capacitor C1 were omitted. The reservoir capacitor C1 filters the rectified DC supply voltage and provides a filter peak DC voltage which is higher than the RMS mains value.

During operation, the magnetic energy stored in the inductor L1 is fed forward to the discharge capacitors C2 and C3 during the charging cycle which has the effect of more rapid recovery of the reservoir capacitor C1 and the discharge capacitors C2 and C3, and also maintains a higher overall voltage across the discharge capacitors C2 and C3.

In this arrangement, the current-limiting resistor R1 is provided in series with the AC supply to stop the in rush current to the reservoir capacitor C1 being excessive at power up and during operation. Optionally, a small capacitor (not

shown) of say 100 µ[redacted]y be connected in parallel with the rect[redacted] D1 on the input, unrectified side.

The provision of the reservoir capacitor C1 and resistor R1 is preferred for modes of operation where the lamp 19 will operate at a high frequency, for example above about 15Hz. However, at lower flash rates, it is not necessary to provide the reservoir capacitor C1, thereby providing a cost saving. In this case, optocoupler O2 is preferably an opto-triac which is switched on to disable the switch S1. This has the advantage that the switch S1 is the only re-enabled at the zero crossing point of the mains cycle. This gives a soft start and hence removes the need for the current limiting capacitor R1 which improves energy efficiency.

Numerous modifications may be made to the capacitive discharge circuit 10 illustrated in Fig. 10, as follows.

In place of separate optocouplers O1 and O2, a single optocoupler (either a transistor circuit or an opto-triac) may be used both to trigger the strobe lamp 11 and to control the switch S1. Preferably, the single optocoupler is arranged to connect a further charged capacitor (not shown) to the gate of the thyristor TH1 when switched on, in order to pulse the control signal applied to the thyristor TH1. The further charged capacitor may be connected directly to the control input of the switch S1. In this case a further resistor will be arranged in series in the line from the charged capacitor to the thyristor TH1 to provide an appropriate time constant to the pulse. For example, the further capacitor and further resistor may have values of 10 nF and 1.5 kΩ, respectively. The further capacitor then remains discharged whilst the optocoupler is on, thereby disabling switch S1 in the usual manner. For charging, this further capacitor may be connected in series with a larger resistor (of say 150 kΩ) between the positive and negative supply rails 27 and 28, so that the rectified DC supply smoothed by the reservoir capacitor C1 charges the further capacitor through the larger resistor. Preferably the voltage on the further capacitor is limited for example by a Zener diode. Pulsing the supply to the thyristor TH1 has the advantage that the thyristor is not held on. This modification requires that the common terminal of the transformer T1 should be tied to the negative rail 28 rather than to the cathode of the strobe lamp 11 as illustrated in Fig. 10.

The unsmoothed supply voltage may be connected, through an appropriate diode and resistor, as an additional supply to the optocouplers O1 and O2 (or single optocoupler if used) and/or to the thyristor TH1 to ensure that these devices can never remain locked on if a fault in the circuit occurs.

Instead of providing the resistor R2, capacitor C4 and transformer T1 separately for each strobe lamp 11, a common trigger circuit may be used to trigger the strobe lamp 11, or the resistor R2 and capacitor C4 may be provided in common for all four strobe lamps 11, to feed respective transformers T1.

For safety, large resistors (of say 330 kΩ) may be connected in parallel with the discharge capacitors C2 and C3 and with the reservoir capacitor C1 to allow leakage of the charge stored on these capacitors when the capacitive discharge circuit 10 is disconnected from the mains AC supply.

Lastly, an additional diode (not shown) may be connected with its anode to the node between the switch S1 and the inductor L1 and its cathode to the positive supply rail 27. The operation of such a diode only becomes significant if the operating frequency becomes higher than anticipated in which case the switch is turned off before the capacitors have fully recharged. In this situation, such a diode will prevent damage to the switch due to over-voltage. It also has the advantage of feeding the excess energy from the inductor L1 back to the reservoir capacitor C1.

With reference to Figure 11, an alternative embodiment of the invention will now be described. This embodiment relies upon a similar arrangement of sensors as described with reference to Figure 1, so the sensor arrangement will not be described in detail again. This embodiment stems from the understanding that a critical source of error in an image display system of the type described here, results from an inaccurate knowledge of the positions of the sensors and the movements (e.g. up and down) of the vehicle relative to the sensors during the passage of the vehicle. Whilst there is a tendency to try to reduce this error by positioning the sensors with ever greater accuracy, this alone will not result in a sufficiently accurate illumination of the images to avoid the imprecise positioning and drift of the image.

The system can be sub-divided into two separate units (indeed these may be physically separate): a processing unit 100 and a timing control unit 101. The processing unit 100 receives timing pulses produced by the various sensors 8,9. The processing unit 100 has a memory in which are stored the relative positions of the sensors 8,9, and a prediction algorithm block 103 for calculating the current speed of a vehicle based upon the time spacing observed between timing pulses produced by any two adjacent sensors 8,9, and the spacing between the two sensors derived from the values stored in the memory. From a sequence of timing pulses received from the sensors, the prediction algorithm block 103 will generate a sequence of speed measurements. By differentiating the speed measurements over time, the prediction algorithm block 103 is also able to generate the acceleration of the vehicle. Both speed and acceleration measurements are passed to the timing control unit 101 via a state vector bock 104. The state vector passed to the timing control unit 101 may also comprise a position which may for example be the trigger for commencement of the operation of the display, i.e. it indicates when the front of the vehicle has arrived at the first detector.

In order to further remove errors from the system, a (simulated) position may be fed back from the timing control unit 101 to a calibration model block 102. This block 102 also receives timing signals from the sensors 8,9 which indicate the true position of the vehicle. As a result of a comparison of the simulated and true positions, correction signals can be passed to the prediction algorithm block 103 causing the speed to be

increased or decreased to synchronise the simulated and true vehicle positions (this may be done gradually to ensure a smooth transition).

The timing control unit 101 relies upon a tunnel digital representation and a train digital representation to generate signals for illuminating the images 2 following the initial detection of a train. As described above, the representations each comprise a sequence of 1's and 0's to represent images and vehicle windows. The representation are shifted relative to one another at a speed and acceleration provided by the processing unit 100, and at each step are ANDed: only if the result is a 1 is a signal is sent to illuminate a corresponding image 2. Of course alternative schemes can be envisaged, for example using a compressed representation where a sequence of successive 0's (or 1's) is represented merely by the number in the sequence.

The processing unit 100 and the timing control unit 101 operate asynchronously of one another. That is to say that the timing control unit 101 will continue to shift the representations relative to one another and generate illumination signals based upon the last received speed and acceleration measurements, and does not interrupt its operation to wait for an updated speed or acceleration value. Of course, when a new speed or acceleration value is provided by the processing unit 100, the timing control unit 101 will adjust the rate at which the representations are shifted. This is a significant feature of the embodiment as it reduces the time criticality of the operations carried out by the processing unit 100: i.e. the processing unit 100 does not need to update or generate speed and acceleration values at fixed intervals (synchronised to the clock rate of the representations shifting operation carried out by the timing control unit 101).

The sensor positions stored in the memory 102 are determined based upon the physical positions of the sensors 8,9 and an analysis of the outputs of the sensors as vehicles pass along the track. Typically, during a setting-up phase, the physical positions of the sensors as measured are stored in the memory 102. A first vehicle is run along the track past the sensors. The speed measurements produced by the prediction algorithm block 103 are statistically analysed and corrected for systematic errors (which might result for example from the an inaccurate knowledge of the positions of the sensors, or from rocking motion or tilting of a carriage which always occurs at a particular

location). From a corrected speed, a corrected sensor position can be determined. The corrected position is then stored in the memory 102 to replace the previously stored value. This process is repeated for a number of vehicles, until the stored positions become stable. At that point, the positions are fixed, and the system can be put into operation. It will be appreciated that the processing unit 100 uses the corrected (virtual) sensor positions to introduce systematic error corrections into both the speed and acceleration measurements. Using this mechanism, an accuracy of better than 0.05% in the positioning of an illuminated image relative to a vehicle window can be achieved. Such a level of accuracy is desirable in order to avoid incorrect positioning of the viewed image or drift of the image.

In a display system comprising a large number of images, it might be appropriate to divide the series of images into subgroups of successive images, e.g. a series of 192 images may be subdivided into eight groups each of twenty four images. Each subgroup is controlled by a separate timing control unit 101. However, each timing control unit 101 receives speed and acceleration measurements from the same processing unit 100. The timing control units are chained together so that each unit receives a timing trigger signal from the previous timing control unit to commence the shifting of the train and image representations. This architecture is advantageous as it enables a display to be easily expanded to include further subgroups of images.

CLAIMS

1. An image display system comprising:

display means for displaying a series of images along the path of a vehicle;

lighting for briefly illuminating individual images;

a plurality of detectors located along the path of the vehicle and arranged to output timing signals as the vehicle passes;

a memory for storing detector positions or relative positions;

processing means for deriving from said timing signals and said stored positions the speed of the passing vehicle, the processing means being arranged to introduce a systematic correction into the derived speed on the basis of an analysis of outputs from the detectors for previously passing vehicles; and

control means arranged to control the lighting to illuminate images successively as the vehicle passes, at illumination timings based on derived speed measurements.

2. An image display system according to claim 1, wherein said stored detector positions are the true positions of the detectors modified on the basis of said analysis, wherein the modified positions provide said systematic correction of the speed measurement.

3. An image display system according to claim 1 or 2, wherein the processing means is arranged to determine the acceleration of a passing vehicle from said timing signals, and to introduce a systematic correction into the derived acceleration, and the control means is arranged to control the lighting to illuminate images successively as the vehicle passes, at illumination timings based on derived speed and acceleration measurements.

4. A method of calibrating an image display system comprising a series of images disposed along the path of a vehicle, lighting for briefly illuminating individual images, a plurality of detectors for detecting the passage of a vehicle along said path, and control means responsive to the outputs of said detectors and recorded positions of the detectors to control said lighting, the method comprising

monitoring the outputs of said detectors during the passage of a plurality of

vehicles, and using the results to adjust the recorded positions of the detectors to calibrate the system.

5. A method according to claim 4 and comprising determining vehicle speeds using the monitored detector outputs and the recorded positions, applying a statistical analysis to the determined speeds, and using the results to adjust the recorded positions.

6. An image display system comprising:

display means for displaying a series of images along the path of a vehicle;

lighting for briefly illuminating individual images;

a plurality of detectors arranged to output measurements of the speed of a passing vehicle; and

control means arranged to control the lighting to illuminate images successively as the vehicle passes at illumination timings based on speed measurements from the plurality of detectors,

wherein the control means is arranged to apply a systematic correction to the speed measurements from at least one detector.

7. An image display system according to claim 6, wherein the control means is arranged to apply, in respect of each one of plural detectors, a respective systematic correction to all the speed measurements from that one of the plural detectors.

8. An image display system according to claim 6 or 7, wherein the at least one detector is arranged to detect the time taken for the vehicle to travel a predetermined distance.

9. An image display system according to any one of claims 6 to 8, wherein the control means is arranged to apply the respective systematic correction by multiplying the speed measurements from the one of the plural detectors by a respective correction factor.

10. An image display system according to any one of claims 6 to 9, wherein:

the detectors include a speed detector arranged to output speed measurements

substantially continuously and at least one timing detector arranged to measure the time for the vehicle to travel a predetermined distance; and

the control means is arranged to apply a correction to the repeated speed measurements from the speed detector based on the output from the at least one timing detector.

11. An image display system according to any one of claims 6 to 10, wherein said control means comprises processing means including a first unit arranged to process the repeated speed measurements to derive an estimate of the current speed of the vehicle and a second unit, operating asynchronously of said first unit, arranged to derive said illumination timings from the instantaneous estimate of the speed of the vehicle.

12. An image display system comprising:

display means for displaying a series of images along the path of a vehicle;

lighting for briefly illuminating individual images;

a speed detector arranged to output measurements of the speed of a passing vehicle continuously;

at least one timing detector arranged to measure the time for a vehicle to travel a predetermined distance; and

control means arranged to control the lighting to illuminate images successively as the vehicle passes at illumination timings based on speed measurements from the plurality of detectors,

wherein the control means is arranged to calibrate the speed detector based on the output from the at least one timing detector.

13. An image display system according to claim 12, wherein the speed detector is a Doppler speed detector.

14. An image display system comprising:

display means for displaying a series of images along the path of a vehicle;

lighting for briefly illuminating individual images;

a plurality of detectors located along the path of the vehicle and arranged to output timing signals as the vehicle passes;

processing means for deriving from said timing signals the speed of the passing vehicle; and

control means arranged to control the lighting to illuminate images successively as the vehicle passes, at illumination timings based on derived speed measurements,

wherein the processing means and the control means operate asynchronously of one another.

15. An image display system according to claim 14 and comprising a plurality of said control means each arranged to control lighting associated with a corresponding subset of said images, the control means each receiving speed measurements from said processing means.

16. An image display system according to claim 15, wherein the plurality of control means are chained together so that in use a given control means receives an illumination timing trigger signal from the preceding control means in the chain.

17. An image display system comprising:

display means for displaying a series of images along the path of a vehicle;

lighting for briefly illuminating individual images;

at least one detector arranged to output repeated measurements of the speed of a passing vehicle; and

control means arranged to control the lighting to illuminate images successively as the vehicle passes at illumination timings based on the repeated speed measurements from the at least one detector,

wherein the control means comprises processing means including a first system arranged to process the repeated speed measurements to produce an instantaneous estimate of the speed of the vehicle and a second system, operating asynchronously of said first system, arranged to derive said illumination timings from the instantaneous estimate of the speed of the vehicle.

FIG.1

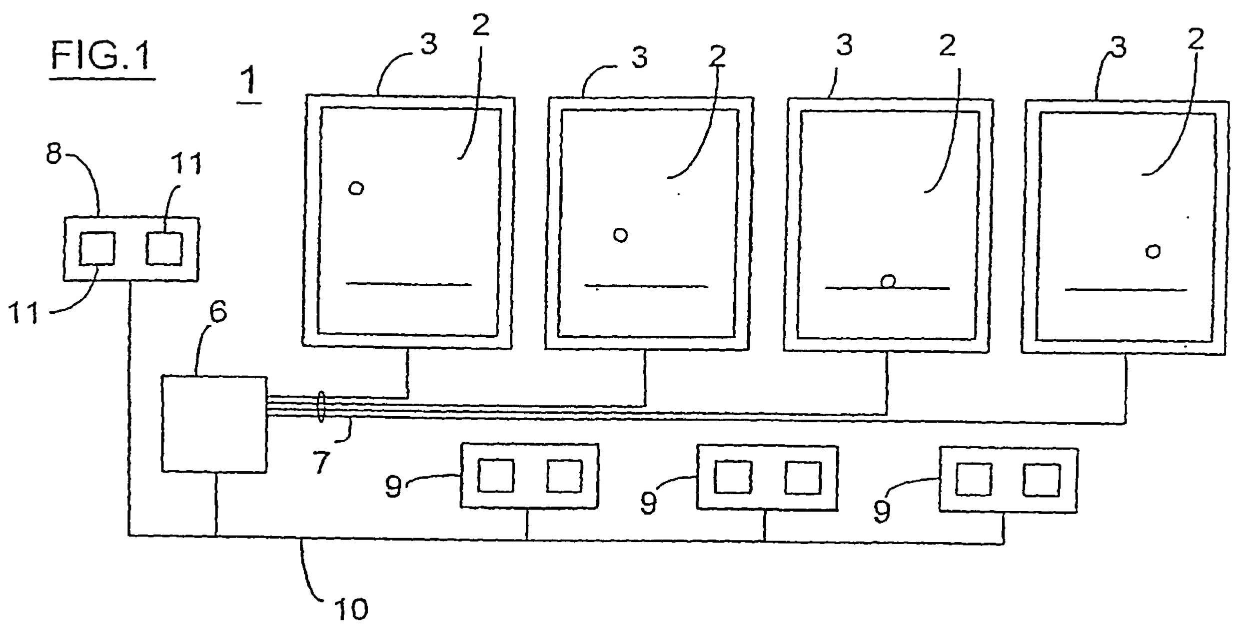


FIG.2

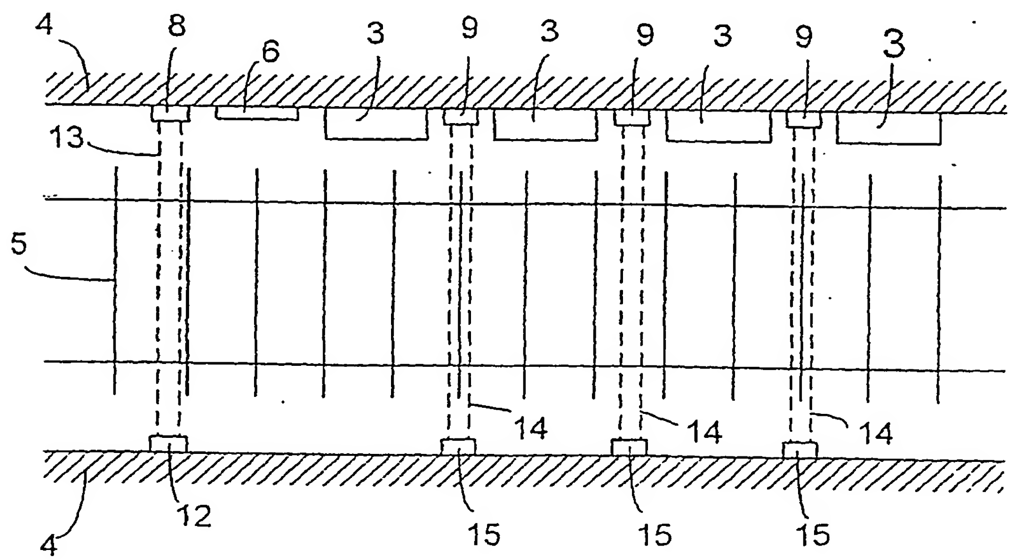


FIG.3

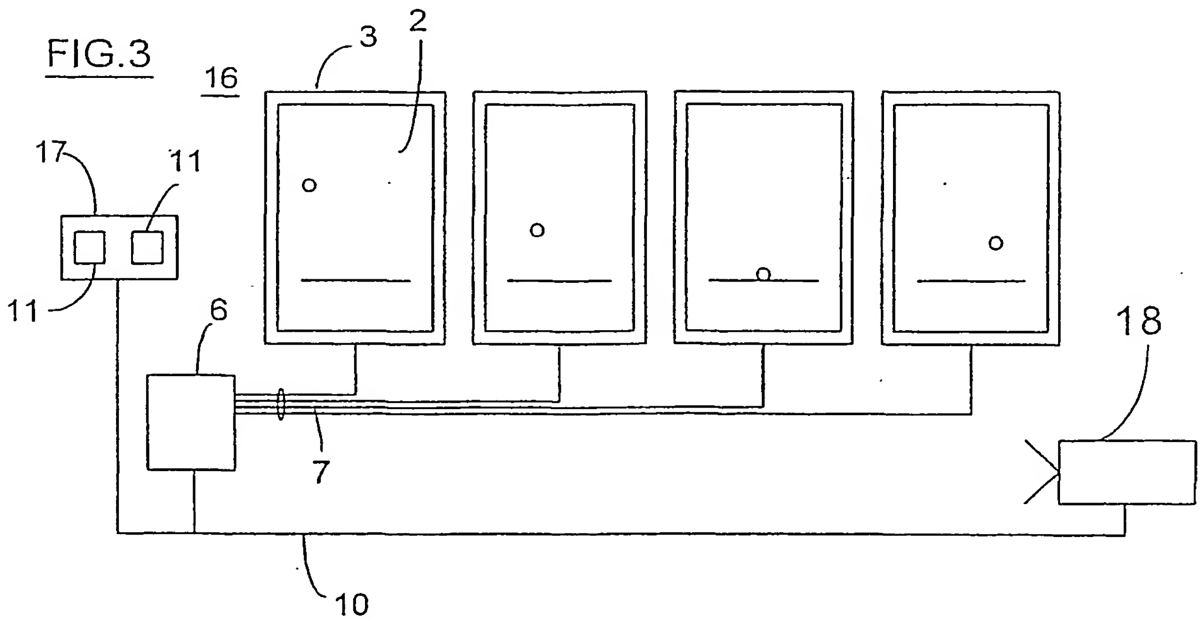


FIG.4

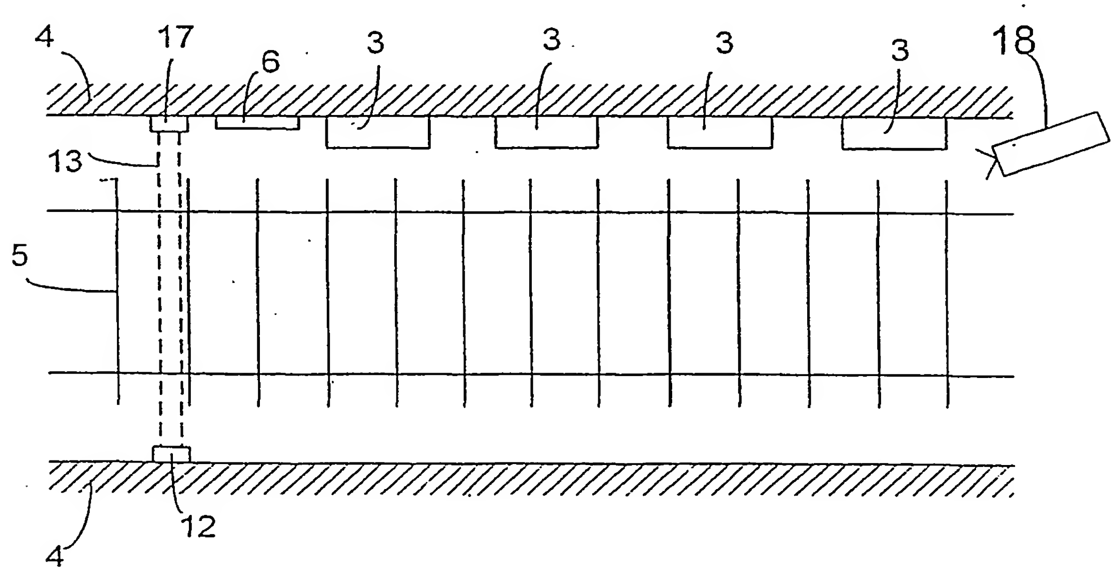


FIG.5

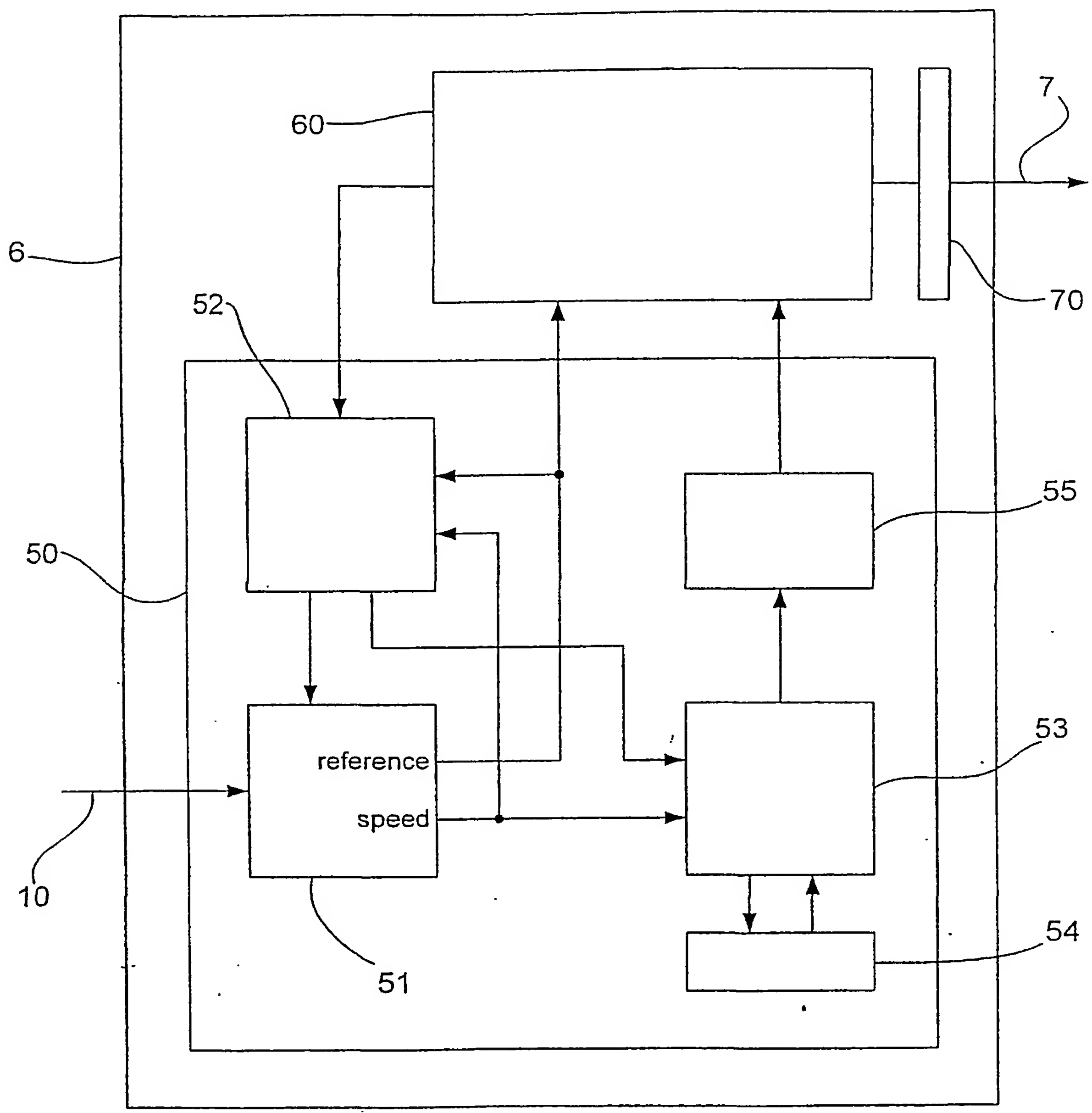


FIG.6

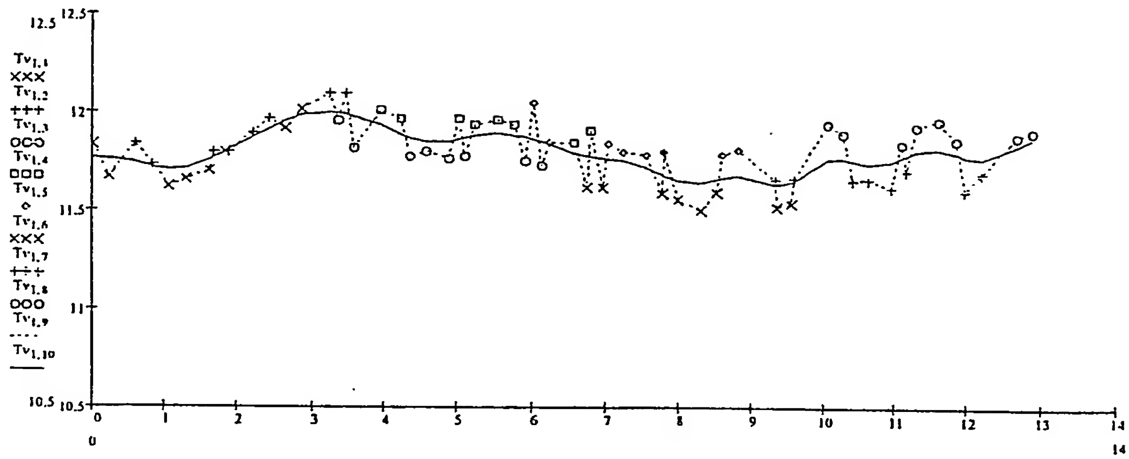


FIG.7

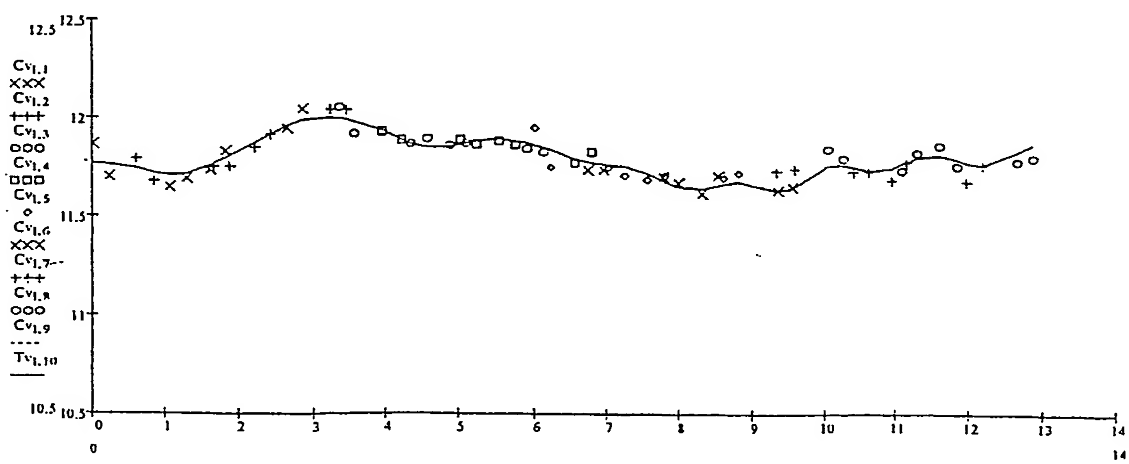


FIG.8

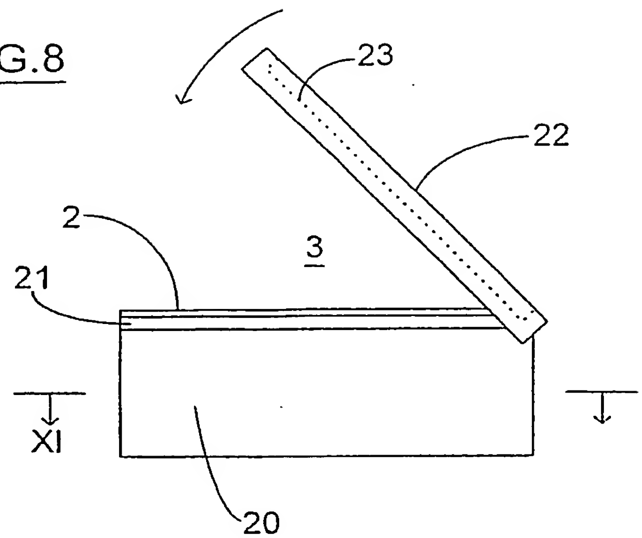
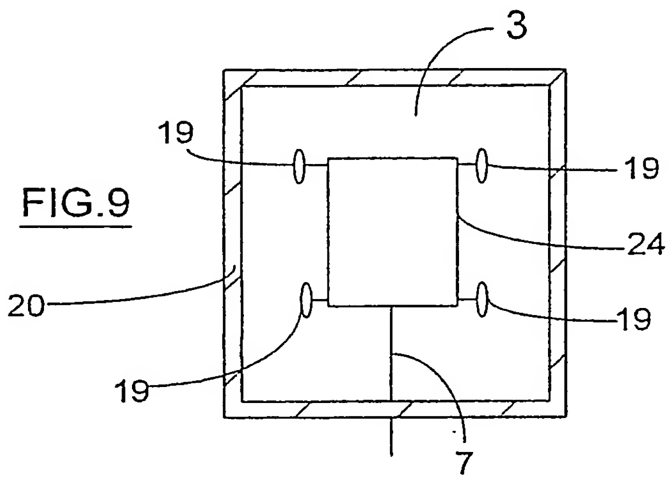


FIG.9



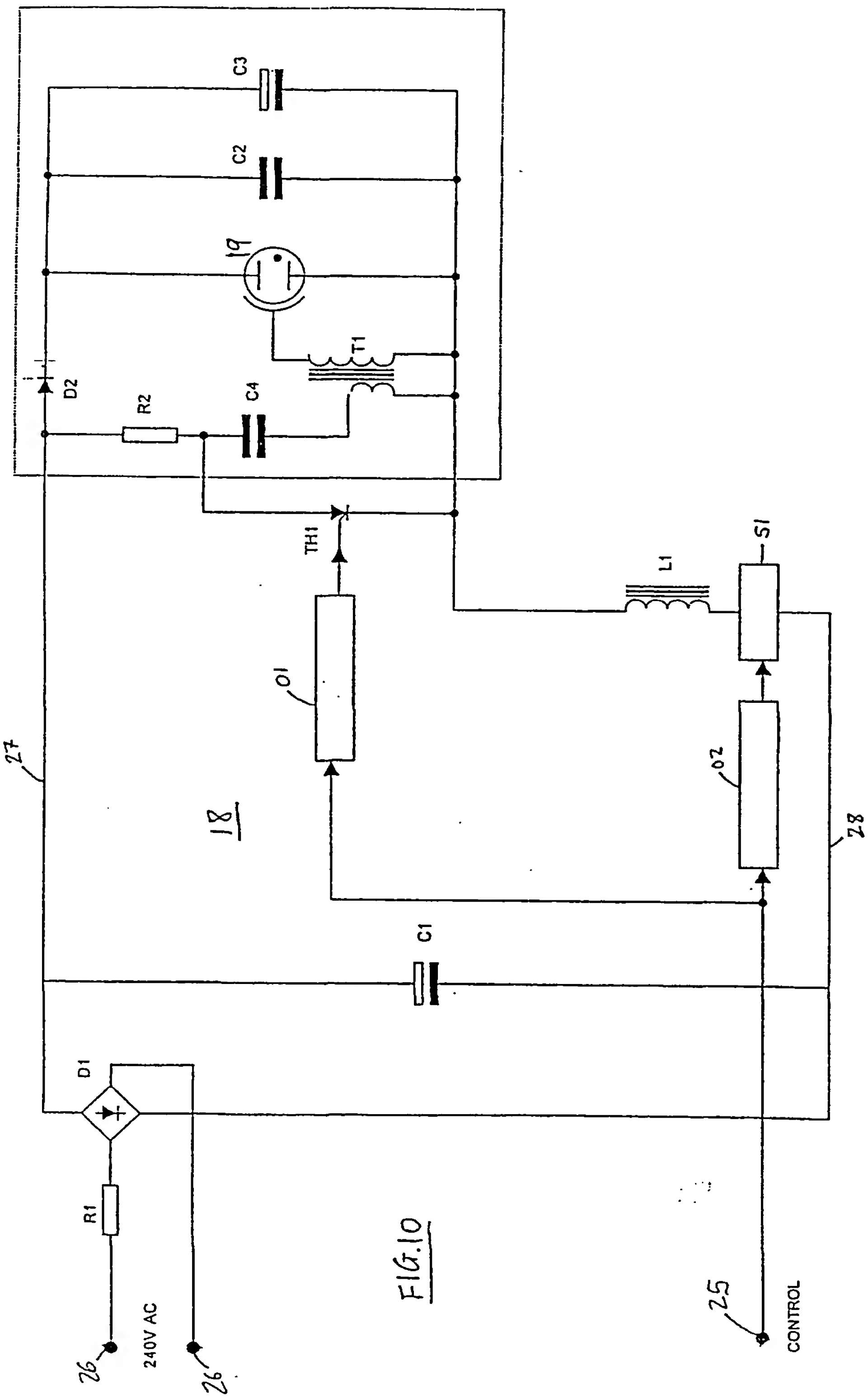

C3
C2
19
T1
D2
R2
C4
TH1
S1
L1
01
02
27
18
28
C1
D1
R1
240V AC
26
26
25
CONTROL

FIG.10

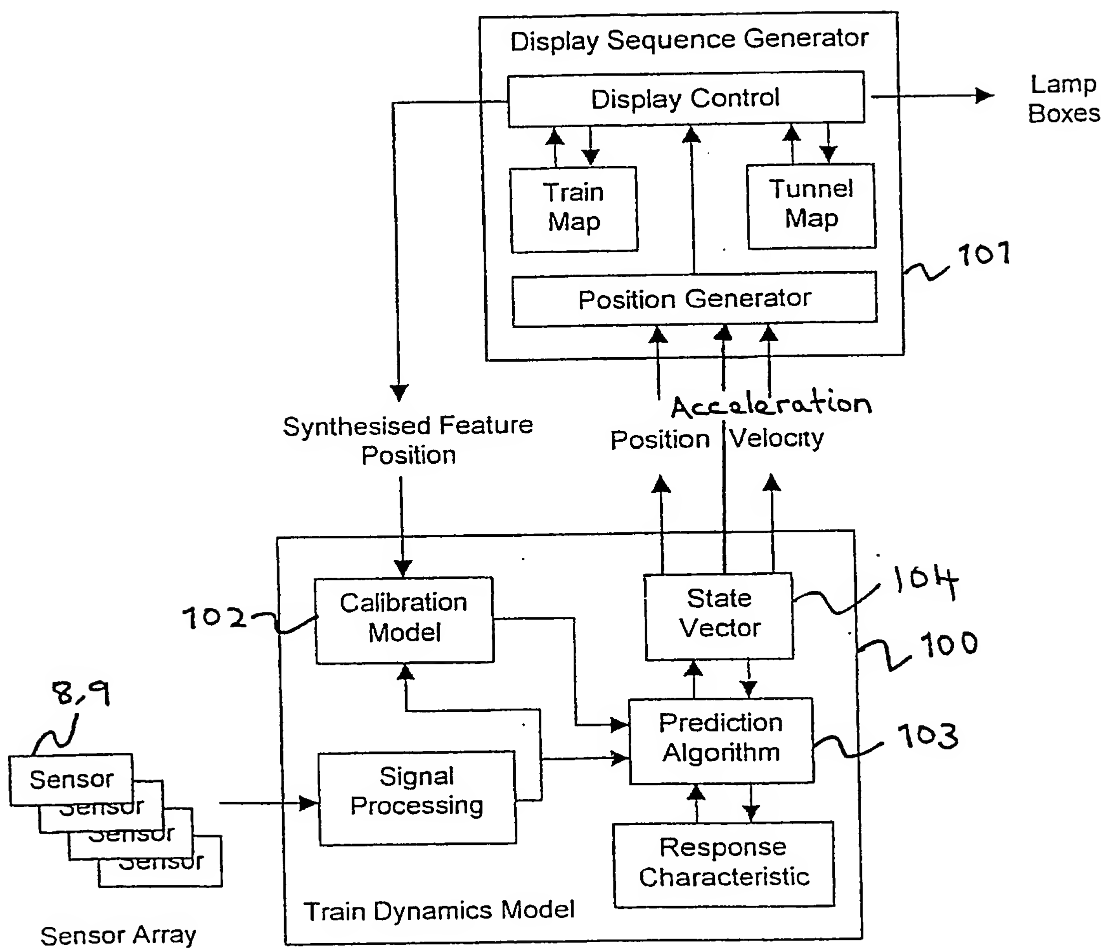

Display Sequence Generator
Display Control
Lamp Boxes
Train Map
Tunnel Map
101
Position Generator
Acceleration
Synthesised Feature Position
Position
Velocity
104
102
Calibration Model
State Vector
100
8,9
Prediction Algorithm
103
Sensor
Sensor
Sensor
Sensor
Signal Processing
Response Characteristic
Train Dynamics Model
Sensor Array

FIG. 11

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(71) Applicant *(for all designated States except US)*: **MOTIONPOSTER PLC** [GB/GB]; 1 The Old Barn, Wicklesham Farm, Farringdon, Oxfordshire SN7 7PN (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **CAUDREY, Jo** [GB/GB]; c/o Evtacon Productions Ltd, St Michael's Business Centre, Church Street, Lyme Regis, Dorset DT7 3DB (GB). **EVEMY, Jeff** [GB/GB]; c/o Evtacon Productions Ltd, St Michael's Business Centre, Church Street, Lyme Regis, Dorset DT7 3DB (GB).

(74) Agent: **LIND, Robert**; Marks & Clerk, 4220 Nash Court, Oxford Business Park South, Oxford, Oxfordshire OX4 2RU (GB).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

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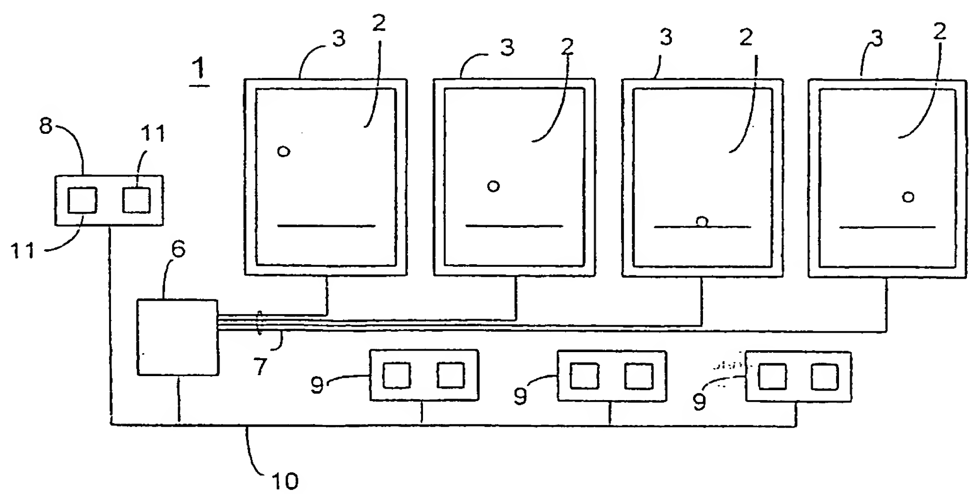
[Continued on next page]

(54) Title: IMAGE DISPLAY SYSTEM



(57) Abstract: An image display system comprising display means (3) for displaying a series of images (2) along the path of a vehicle; lighting (19) for briefly illuminating individual images (2); a plurality of detectors (8,9) arranged to output measurements of the speed of a passing vehicle; and a control unit (6) arranged to control the lighting to illuminate images successively as the vehicle passes at illumination timings based on speed measurements from the plurality of detectors. The control unit (6) is arranged to apply a systematic correction to the speed measurements from the detectors (8,9) based on a statistical analysis of the speed measurements from all the detectors (8,9), which can reduce drift and jitter. The control unit (6) includes a dynamics processing unit (50) arranged to perform non-linear predictive filtering of the speed measurements to produce an instantaneous estimate of the vehicle speed. The control unit (6) also includes a timing generator (60) operating asynchronously of the dynamics processing unit (50) and arranged to derive the illumination timings from the instantaneous speed estimate.

WO 02/21488 A3

Published:
— *with international search report*

(88) Date of publication of the international search report: 16 May 2002

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 01/04020

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G09F19/22 G03B25/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G09F G03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 989 535 A (SONY CORP ;YAMAMOTO MASAOMI (JP)) 29 March 2000 (2000-03-29) column 2, line 41 -column 4, line 30 column 5, line 55 -column 6, line 20 column 7, line 8-19; figures 1,2,6 ---	1-4,6-11
X	DE 31 05 820 A (HOCHBERG PETER;KEMPIS THOMAS) 26 August 1982 (1982-08-26) page 3 -page 4 page 10 -page 11; figures 1,2,9 -----	1-4,6-11

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 December 2001	01.03.02

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	JANDL, F

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB 01/04020

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-11

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-11

   An image display system displaying a series of images along the path of a vehicle
   comprising lighting means, detector/processor means for time/speed measurements and control means for illuminating the images.

2. Claims: 12, 13

   An image display system substantially as in claim 1 further using a Doppler speed detector.

3. Claims: 14-16

   An image display system substantially as in claim 1 further comprising asynchronous operation of processing and control means as well as lighting only a subset of images, whereby illumination is triggered from the preceding control means.

4. Claim : 17

   An image display system substantially as in claim 1 further comprising control means with two separate systems for speed and illumination timings estimation respectively.

ERNATIONAL SEARCH REPORT

formation on patent family members

ernational Application No

PC./GB 01/04020

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0989535 A	29-03-2000	JP 2000162994 A	16-06-2000
DE 3105820 A	26-08-1982	NONE	